Application for United States Letters Patent

of

Robert Wilhelm Schumann

David G. Grossman

David Glen DeGroote

for

Visual Copyright Protection

VISUAL COPYRIGHT PROTECTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of priority to provisional patent applications: Serial No. 60/199,134 to Robert Wilhelm Schumann and David G. Grossman, filed on April 24, 2000, entitled "Visual Copyright Protection," which is hereby incorporated by reference; Serial No. 60/273,318 to Robert Wilhelm Schumann and David G. Grossman, filed on March 6, 2001, entitled "Visual Copyright Protection," which is hereby incorporated by reference; and Serial No. 60/280,148 to Robert Wilhelm Schumann, David G. Grossman and David Glen DeGroote, filed on April 2, 2001, entitled "Visual Copyright Protection," which is hereby incorporated by reference.

[0002] BACKGROUND OF THE INVENTION

[0003] The present invention relates generally to the field of visual copyright protection. More specifically, the present invention relates to the generation of optical signals that impede the ability of recording devices to make copies of the content.

[0004] It is a known problem that pirates videotape content for which they have no rights such as movies, concerts, and proprietary events. Often, copies of these recordings are sold for profit by the pirates or distributed for free (for example, over the internet), depriving revenue to the rightful owners of the content. To date, no

methods and apparatuses have been commercially utilized to protect this content from being effectively recorded.

[0005] The following terms are useful in discussing visual image generation and disruption.

UV - Ultraviolet light whose frequency is greater than or equal to 0.200nm and less than or equal to 0.400um.

VIS - Visible light whose frequency is greater than or equal to 0.400nm and less than or equal to 0.700um.

NIR - Near infrared light whose frequency is greater than or equal to 0.700nm and less than or equal to 1.400um.

NVIS - Non visible light whose frequency is less than 0.400um or greater than 0.700um.

Content - Any optical information created for presentation to either a human eye or recording device.

IRD - Any image recording device capable of recording single or multiple optical images such as a camcorder, digital camera, or film camera.

IGD - Any image generating device capable of generating an optical image including film projectors, monitors, displays, spot lights, and other lighting devices. Some technologies used by IGD's may include LCD's, MEM's, IDLA's, and optical irises.

[0006] One previously discussed solution involves blasting a movie theater audience with a constant source of infrared light. This blasted light has such intensity that it

washes out the visible light in any image recorded by an IRD. A serious drawback to this solution is that IRDs may be fitted with infrared filters to filter out this constant infrared signal.

[0007] There is sufficient evidence in the prior art that solving piracy of content is a serious issue. A series of patents have addressed the problem of preventing video reproduction through the modification of electronic video signals. Other patents address the issue of preventing the copying of paper based and photographic content. Further, several patents deal with the issue of limiting access to multimedia content. Other patents deal with adding watermarks to content to later prove that copying has taken place. All of this prior art is trying to solve the serious problem of illegal piracy of content. There is still a need to solve the serious problem of piracy of content such as movies in theaters, live performances, and protected areas by IRDs and other electronic image detecting devices.

[0008] U.S. patent number 3,963,865, entitled “Anti-Piracy Method and System” to Songer discloses a method and system for eliminating or deterring the unauthorized duplication or piracy of video program material, including video tape, cable and broadcast television material. Songer’s patent does not address the parallel problem of eliminating or deterring the unauthorized duplication or piracy of optical program material, including movie presentations in theaters, presentations of live content such as concerts, or pieces of art on display in museums. Songer ‘865 attempts to thwart piracy by encoding a composite video signal when recording content. The encoding method allows normal playback of the content on televisions, but prevents the

content from being effectively rerecorded or duplicated on commercial recorders by distorting the recording and thereby destroying its commercial value. Similarly, an optical system to thwart piracy is needed whereby the optical content may be viewed normally when first presented but prevents the content from being effectively rerecorded or duplicated on commercial recorders by distorting the recording and thereby destroying its commercial value.

[0009] U.S. patent number 4,631,603 entitled "Method and Apparatus for Processing a Video Signal so as to Prohibit the Making of Acceptable Video Tape Recordings Thereof" to Ryan discloses an invention which modifies a video signal so that a television receiver will still provide a normal color picture from the modified video signal while a videotape recording of the modified video signal produces generally unacceptable pictures. Like the Songer patent, this patent evidences the need for protecting content from pirates. The present invention also addresses the need to protect content from pirates. The Ryan patent seeks to prevent pirates from copying video content through hard wiring copying methods. The present invention prevents pirates from copying displayed content optically using IRDs.

[0010] An example of a device which attempts to limit access to copyrighted content is disclosed in U.S. patent number 5,907,656 entitled "Apparatus and Method for Reproducing Video Signals with Varying-Magnitude AGC Signals" to Oguro. This patent disclosed a signal format and compatible reproducing apparatus which uses the disclosed signal format to protect the copyright of recorded video and audio data against dubbing. This patent requires that both the signal and the hardware used to

duplicate the copyrighted content be compliant with the system disclosed. Needed is a copy protection scheme which is independent from compliant hardware on the part of the pirate.

[0011] U.S. patent number 5,680,454 entitled "Method and System for Anti-Piracy Using Frame Rate Dithering" to Mead discloses a method and system of displaying an image sequence containing a plurality of image frames to inhibit an unauthorized duplication thereby by a camera by varying the frame rate in dependence upon a pseudo-random noise sequence about a nominal frame rate. This patent attempts to prevent pirates from duplicating a displayed sequence by slightly modifying the frame rate of the displayed sequence, thus making it difficult for the pirates' IRD to synchronize with the displayed sequence. This method may not work with new IRDs whose electronics are much more sophisticated and are capable of synchronizing automatically to slightly varying frame rates. In post-processing the resultant luminescence change is also easily removable using modern video editing tools. Also pseudo random changes in frequency may be easily perceived by humans. In addition, this method affects the displayed image globally, not allowing for selective modifications of an image where effects are most likely to be advantageous. Further, this patent does not disclose a system that may prevent the recording of live performances or protected areas.

[0012] Needed is a way to protect content from unauthorized, high quality copying by IRDs, while minimizing human perceivable defects. Such a system should prevent a modern IRD or other types of electronic optical detection systems from recording

optically displayed images in whole and in part, and similarly prevent the recording of live performances or protected areas.

SUMMARY AND ADVANTAGES OF THE INVENTION

[0013] One advantage of the invention is that it generates visual images that impede the ability of recording devices to make copies of generated visual images.

[0014] Another advantage of this invention is that it may generate content specific disruptions.

[0015] Another advantage of this invention is that it may be implemented using a variety of different projection and display systems, including systems used with prerecorded and live content.

[0016] Yet a further advantage of this invention is that it may protect both analog and digital content.

[0017] To achieve the foregoing and other advantages, in accordance with all of the invention as embodied and broadly described herein, a method for visual copyright protection comprising the steps of inputting light from a light source, selecting a disruptive light modulating pattern based upon a criterion, the criterion being how the pattern is perceived by an IRD and a human differently, modulating a light array having at least one element using the disruptive light modulating pattern, projecting the light onto the light array producing a modulated light beam, and outputting the modulated light beam. The light array may comprise a multitude of light arrays.

[0018] The criterion may further include selecting the pattern for the purposes such

as inserting a watermark, inserting a human perceivable image, inserting a non-human perceivable image, creating disruption effects, or creating disruption effects containing motion. The criterion as well as disruption patterns may be inputted from an external source or based upon a dynamic analysis of source content.

[0019] In a further aspect of the invention, the method for visual copyright protection may further include the step of projecting the modulated light beam onto a surface. The surface may be an image bearing surface. The modulated light beam may also be focused near the surface. The surface may be utilized by a projector.

[0020] In a further aspect of the invention, the method for visual copyright protection may illuminate an area with the modulated light beam.

[0021] In a further aspect of the invention, the disruptive light modulating patterns may modulate each element differently. Disruptive light modulating patterns may be provided from an external source and may be a multitude of disruptive light modulating patterns;

[0022] In yet a further aspect of the invention, the method for visual copyright protection may further including the steps of: receiving an input image, and combining the input image with the disruptive light modulating pattern. The disruptive light modulating pattern may be a multitude of sequenced disruptive light modulating patterns.

[0023] Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by

practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The accompanying drawings, which are incorporated in and form a part of the specification, illustrate an embodiment of the present invention and, together with the description, serves to explain the principles of the invention.

[0025] Figure 1 is a block diagram of an aspect of the present invention utilizing two projectors.

[0026] Figure 2 is a block diagram of an aspect of the present invention showing a disrupter system.

[0027] Figure 3 is a block diagram of an aspect of the present invention showing a disrupter projection system.

[0028] Figure 4 is a block diagram of an aspect of the present invention showing a disrupter projection system including a multitude of subprojectors.

[0029] Figure 5 is a block diagram of an aspect of the present invention showing an image disrupter system including a disruption shutter.

[0030] Figure 6 is a block diagram of an aspect of the present invention showing an image disrupter between a light source and a projector.

[0031] Figure 7 is a block diagram showing possible locations for a disrupter in a projection system.

[0032] Figure 8 is a flow diagram showing possible content processing steps.

[0033] Figure 9 is a block diagram of an aspect of the present invention showing a split light path.

[0034] Figure 10 is a block diagram of an aspect of the present invention showing a disrupter feeding a projector.

[0035] Figure 11 is a block diagram of an aspect of the present invention showing a disrupter and projector in combination.

[0036] Figure 12 is a block diagram of an aspect of the present invention showing a light switch array.

[0037] Figure 13 is a block diagram of an aspect of the present invention showing DMD data loading.

[0038] Figure 14 is a block diagram of an aspect of the present invention showing a DMD device.

[0039] Figure 15 is a timing diagram of an aspect of the present invention showing signals used in loading DMD data.

[0040] Figure 16 is a block diagram of an aspect of the present invention showing a DMD controller.

[0041] Figure 17 is a block diagram of an aspect of the present invention showing a image generator using image transpose logic.

[0042] Figure 18 is a block diagram of an aspect of the present invention showing a image generator with dual image transpose logic.

[0043] Figure 19 is a block diagram of an aspect of the present invention showing

pattern disruption generation.

[0044] Figure 20 is a diagram of an aspect of the present invention showing insertion of disruption text on an image.

[0045] Figure 21 is a diagram of an aspect of the present invention showing a multitude of font projection sequences.

[0046] Figure 22 is a block diagram of an aspect of the present invention showing an image disruption technique.

[0047] Figure 23 illustrates a light switch array and a mirror combination wherein the light switch array occupies an area of the mirror.

[0048] Figure 24 shows an attack based upon the interlace processing on some IRDs.

DETAILED DESCRIPTION OF THE INVENTION

[0049] The present invention solves a long-standing problem of pirates making illegal copies of visual images. The present invention solves this problem by generating optical effects that may be invisible to humans but may also be difficult for an IRD to record. Generating these optical effects may be done by taking advantage of differences between a human's ability to see and perceive an image and the ability of an IRD to record the same.

[0050] Multiple techniques may be combined or utilized individually to produce images that are difficult to record. A first disruptive technique includes creating signals that are invisible to the human eye, but are visible to an IRD, wherein the IRD

records the projected signals as images in the visible spectrum. Imaging sensors, within IRD's, typically break their signal into a few individual signals such as red, green and blue; or cyan, magenta and yellow. Display systems are designed so that these discrete signals when viewed together produce a full spectrum of colors. However, the image sensors often include in the individual signals, energy from NVIS signals. This energy from the NVIS signals may ultimately become visible during recording and subsequent image reconstruction.

[0051] Some disruptive techniques may be directed to disrupting the operations of the IRD, including sets of command signals to the imaging devices such as IRDs. For example IRD's with command signal receiving ports may be commanded to operate in a manner contrary to recording the content. Typically, such command signals are NIR signals, but may include any NVIS, VIS, or radio frequency signals.

[0052] Another technique to disrupt the operations of the IRD may involve including NVIS or VIS signals to confuse the auto-focus of an IRD . Further techniques may include using NVIS signals to confuse the imaging devices exposure means, causing under and overexposed images. Varying the intensity of these signals may cause constant variation in the final recording.

[0053] Yet another way of disrupting the IRD's ability to record an accurate copy of an image may include varying the timing of the displayed image. Many IRD's use sensors that have electronic, or mechanical, shutters that operate at various rates. The IRD's may also have electronics that generate output images around standard frame rates. Producing images that are basically incompatible with the timing of the

IRD may result in anomalous images. For example, producing an image whose timing is off may produce beat frequencies that are visible as scrolling bars, image blotches, etc. This effect may also be generated by introducing an image interrupter, such as an independent shutter, into a normal projector that may be synchronous or asynchronous to the frame speed of the content projection. Running the interrupter at a rate different than the video scanning rates, may also generate anomalies such as attenuated areas across the IRD's output image. The timing of generated content may be modified over time to cause undesirable variations in the image on many different IRD's that may have different characteristics. This shutter effect may be predetermined to maximize the attack on each of the many IRD's available for use by content pirates. A disrupter able to generate a shutter effect may be inserted at almost any position in a projected light path. For example, one may insert the disrupter between a lamp and a projector, or between a projector and a projector lens.

[0054] Depending upon the IGD technology used, the timing variations introduced to generate beating effects may occur on different blocking structures such as lines, columns, circles, or pixels. And further, the timing variations may be introduced through high or low frequency beat components, potentially in conjunction with the display capabilities of the IGD.

[0055] The effective response time of some display technologies may be improved by combining display elements. In these embodiments, it may be possible to switch the elements on and off quickly and accurately, although their latency may be high.

[0056] Yet another method for generating a disruption effect includes inserting spaced marks into the generated image that are spaced so as to coincide with the spacing of the image elements on the image sensing devices optical sensors. When the spacing is some percentage off from the image elements spacing, interference patterns, sometimes known as moiré patterns, may be produced in the recorded image. An image element may include a single pixel, a group of pixels or an image frame. A generated image may include any modulated image generated by any IGD including a projector, a projector lamp, or a spot light.

[0057] Disruption content may have a multitude of new content including but not limited to images with anomalies, black frames, random patterns, intensity variations, and other predetermined patters such as moiré patterns. If the generated images are of a reduced intensity, the human eye may not detect them. However, because of the timing of the imaging device, the generated images may be captured and reconstructed for much longer periods of time, creating anomalous images.

[0058] In an environment where display content is generated using subframes, the present invention may generate images using a higher rate where displayed content is time-multiplexed with disruption content. The disruption content may become visible when played after being processed by an IRD due to temporal expansion facilitated by timing differences between the IRD and IGD.

[0059] Additionally, separately generated frames may be projected. Each additional frame may add new content and effects. For example, such a system may be

implemented using a multi projector system. The resultant effect may be the sum of each of the separate effects.

[0060] Implementing the present invention in environments where human visible images are generated by pulse width modulation techniques, such as in a DLP based projector, disruption techniques may be generated by using different pulse width modulation patterns both spatially among different pixels within a frame, as well as temporally for the same pixel in different display frames. Note that these techniques can also be combined.

[0061] Images produced by the disclosed techniques may distort current images, or create new ones. In the case of producing new images, those images may include but are not limited to text or logos identifying the content as copyright protected. Further, the content may also include identifying information or watermarks such as but not limited to location and time of the event being recorded.

[0062] In some instances, it may be desirable to use the present invention to generate human perceivable visual images. Such images may be used to mark the content with messages such as "test showing", "proof", "sample", "copy protected", or the like. This same capability may also be used to customize presentations such as advertisements. A generic advertisement in the content may be modified to present a local message to an audience during display.

[0063] The present invention may also be utilized in conjunction with standard film projectors, LCD based projectors, D-ILA based projectors, with Digital MEMS projectors, or any other light projecting or modifying apparatus. A disrupter as

described may also be used in multiple modes. For example, the disrupter may be used as a disruptive light source to a conventional projector in one mode and as a discrete digital projector in another mode. In other words, we may have a digital projector that may also be used as a disruptive light source for other IGD's such as a conventional film projector In this case the combined units may share common elements such as projection lenses, power supplies, cooling, and mechanical mounting.

[0064] An interlock to automatically enable these techniques when an electronic digital content security system exists may be included as part of the system to ensure that the content may only be generated utilizing anti-copying measures. The electronic digital content security system may, for example, be used synchronously with live, film, or digital based content.

[0065] An example of a disruption pattern which can be generated may include a stripping effect where alternate high speed source frames have interleaved data being displayed. The IRD records all or portions of the stripped frames, while the human viewer observes a continuous image.

[0066] Another example of disruption patterns may include: a message display where a visible message (i.e. "COPY") is displayed using techniques disclosed herein; and generating a localized disruption which may obscure the highest value portion of the image such as a star's face. The disrupter may have an external data source which directs where and how to disrupt the content based on specific characteristics of the content. Such an external data source may be synchronized

with the content being displayed. For example, in a film based embodiment, the synchronizing information may be carried in the sound track area of the film, or timing information may be carried on the film for synchronizing with externally provided disruption directives. These externally provided disruption directives may be delivered through any standard electronic delivery mechanism such as modem connections, internet connections, hard media, or satellite. Correspondingly, in a full digital version, this information may also be in the control stream, or carried in the actual digital film data itself, whether compressed or uncompressed. The control information may determine characteristics of the disruption such as the area or zone of the frame to be disrupted and which effect to produce in that zone. The localized disruption may be pre-authored or dynamically calculated.

[0067] Additionally, effects may be feathered in around their edges. Feathering may have the advantage of avoiding sharp discontinuities that may become visible to the naked eye.

[0068] The disruptive effects may be optimized based to the particular content being displayed at any particular time. Any type of disruptive effect may be optimized to the content including playback flicker frequency, moirés, and moving patterns such as waves. For example, an effect that is especially effective on a blue sky may be applied to only blue skies and not the ground below. The time that different disruptive effects are invoke may also be selectively chosen based on various criterion such as the emotional level of the content or the visual intensity of the content. In addition, the location of the effect may be optimized to the content. For

example, the effects may be directed to the central focal point of the content and avoided in peripheral areas.

[0069] Disruptive effects may include both discrete effects visible within individual images as well as dynamic effects over a multitude of images. These dynamic effects may be comprised of a series of effects on discrete images such that when viewed in a continuous fashion cause additional disruption. For example, a flickering bar could be shifted slowly to distract the attention of a viewer from the underlying image. Other dynamic disruption effects could include spinning alternate wheels, and adjacent shifting vertical bars where one bar is moving up and the other bar is moving down.

[0070] In a live performance embodiment, these changes may be controlled dynamically either by a transponder on stage or by a director. In addition, the disrupter may be used to replace visible content. In this way, content may be customized for uses such as advertising.

[0071] In some instances, it may be desired to provede ant-piracy lighting effects to "protected areas." Such areas may include museums or high security locations where there is a desire to prevent pictures from being taken. Entire rooms or specific areas may be targeted by the present invention. Objects in settings such as museums may have individual lighting to protect them, whereas a reception area may have full room lighting effects.

[0072] To compensate for a decrease in intensity that may occur by implementing some of these techniques (particularly within existing film based projection systems),

the luminance of a projector may be increased and then the effective duty cycle of the projected frames may be decreased by a similar amount so that the average luminance is unaffected. The content data average may be the average intensity of the content data. The display data average may be the average intensity of the display data. Preferably, the content data average will be equivalent to the display data average. One skilled in the art will recognize that other techniques may also be used to control intensity including controlling the density of content such as on film prints.

[0073] By implementing a multitude of disruptive mechanisms, an increased degree of protection may be created. Several of these mechanisms may be "switched" in and out over time to confuse the IRD's and pirates. In addition, both visible and invisible effects may be "switched" in and out over time, allowing completely visible effects to be presented. Hence, only one of the disruptive mechanisms needs to work to achieve the stated goal of IRD's from recording high quality images.

[0074] Reference will now be made in detail to the presently preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings.

[0075] Referring now to figure 1, we see a system with a controller **110** that is controlling two projectors, a first projector **100** and a second projector **120**. Projector **100** has a shutter **102** and a lens **104**. Projector **120** has a shutter **122** and a lens **124**. Controller **110** controls the shutters **102** and **122**. The two projectors project images synchronously with each other. The first projector **100** produces image beam **130** and the second projector **120** produces image beam **132**. Image beams **130**

and **132** are reflected off screen **140** as a composite beam **540**. IRD **160** then receives the composite image **540**. In the illustrated example, a first projector **100** is preferably projecting regular content while the second projector **120** may be projecting disruptive content. Alternatively, controller **110** may only control the second projector **120** based on synchronization information from the first projector **100**. It this case the controller **110** is not controlling the first projector **100**. Lamps in the two projectors may produce light of different frequencies to assist in generating a disruptive effect. The disruptive content may include: variously timed signals; nonvisible light signals; locally disruptive signals that may be directed to particular parts of the image, or the entire image. This embodiment may also generate subtitles. The original images may be generated by a multitude of sources including film, and digital distributions.

[0076] Figure 2, is a block diagram of a disruption processor system as per an embodiment of the present invention. A disruption processor **200** processes and disrupts the input content **250**. Input content **250** is input to the disruption processor **200** and may include content data **254** and/or a content clock **252**. Disruption content **220** may also be input into the disruption processor **200** and may include disruption data **230** and/or a disruption clock **240**. A multitude of means including optical or electrical means may provide content or information to the image disrupter **200**. The disruption processor may process the input content **250** from its original content clock rate to a new display rate using the disruption clock **240** and the disruption data **230**. The disruption processor **200** preferably introduces disruption

components as specified by the disruption data **230** into the output signal as disruptive effects. The output signal may include a display clock **270** and/or display data **280**, and is preferably output to a light array **210**. An image display system **210** may include but is not limited to a MEM's display device, an LCD display device, a CRT display device, a light projector, or an artificial eyelid device. The resultant image that is displayed on the image display system **210** preferably looks normal to the human eye, but may contain anomalies that appear in the recorded image. Some of the disruption components are preferably selected to interfere with the normal shutter speed, scan rate, or low frequency (approximately 50 to 60 Hz.) synchronization circuitry of the input sensor of an IRD trying to record the content as described earlier.

[0077] The implementation described in Figure 2 may be realized, for example, using DMD technology from Texas Instruments of Dallas TX. This technology uses a modulated reflection of a continuous light source using an array of high-speed movable mirrors to modulate the light output for a source frame element to the correct luminance for that frame. The reflected output may be used as a light source to a conventional projector, or as a direct image source itself. In this system, the display frame rate is typically a much higher frame rate than a conventional source frame rate of 30 HZ. Currently the high-speed frame generation systems provide a very uniform modulation of the image. In fact, much work has been done to make images as even and smooth as possible. For example, U.S. patent number 5,619,228 entitled "Method for reducing temporal artifacts in digital video systems" by

Doherty discloses a method and system for improving display of digital video data. The present invention specifically modifies the standard modulation algorithms to introduce frequency patterns which may cause anomalous images to be recorded by IRD's.

[0078] Figure 3 illustrates a projector **300** built as per an embodiment of the present invention. Input to the projector **300** is source data **310.** Source data **310** may originate from the content media or from other external sources. The source data **310** is processed by a disruption processor/controller **320**. One output of the disruption processor/controller **320** may control a lamp **324**. The other output of the disruption processor/controller **320** may control a light switch array **322**. The light switch array **322** which may include a digital DMD device, an LCD, or other type of manipulating array. Light from the lamp **324** is projected through a first Optics **326** which reflect the beam onto the light switch array **322**. Preferably, the light switch array manipulates the light on a pixel-by-pixel basis at a higher rate than the source frame rate and reflects the resultant image to optics **328** where a main image beam **320** is projected onto a screen **340**. An IRD **360** receives a reflected beam **350** reflected from screen **340** or other illuminated space. The embodiment illustrated in figure 3 may have uses including a disruptive spotlight, a lamp source for a still or moving projector, a lighting system, or a self-contained image projection system.

[0079] Figure 4 shows a projection system demonstrating the combined use of a multitude of projectors. The content source **400** is input into a controller **402**. The controller then controls three subprojectors: subprojector A **400**; subprojector B **412**;

and subprojector C **413**. Subprojector A **410** produces an image beam **420**, subprojector B **412** produces an image beam **422**, and sub projector C produces an image beam **424**. The three image beams **420**, **422**, and **424** may be combined in optics device **430** into a single image beam **440** which may be reflected off of a screen **450** and received by an image sensor **470**. Each of the subprojectors preferably work in unison to produce a series of images that when combined by the optics device **430** contain disruptive signals directed to the imaging device **470**. These disruptive signals may be generated in either one or all of the subprojectors. Examples of this type of system that may be modified to implement embodiments of the present invention include the ELM G10 and ELM R12 projectors by Barco located in the Netherlands which use multiple DMD chips from Texas Instruments, where each chip modulates one of Red, Green and Blue portions of the image.

[0080] Figure 5 illustrates another aspect of the invention. In this example, a traditional projector **510** is fitted with a disruption shutter **512** and a lens **514**. A disrupter device **500** may control the disruption shutter **512** and the projector. The disruption shutters may include devices such as traditional shutters, LCD shutters, or artificial eyelids and may shutter a complete image or just a portion of the image. A key feature of these disruption shutters, relative to this invention, is that they are capable of operating at a rate in excess of the human visual perception rate of 60-80 HZ. The projector may project image beam 520 onto screen 530. An IRD **550** may then receive reflected beam **540** from screen **530.** This embodiment could be used as a spotlight in a museum to protect items on display from being photographed.

[0081] Figure 6 is a block diagram of an aspect of the present invention showing an image disrupter **620** between a light source **610** and a projector **650**. Light source **610** generates light that may project through an input lens **630** and onto a DMD. The input lens **630** preferably collimates the light beam. The DMD may be an array of mirrors, wherein each mirror in the array may be independently steered. Each of the mirrors preferably reflects a portion of the light beam either through the output lens **634** or into a light sink. The light source 610 may be the light sink. The portion of the light beam reflected through the output lens **634** may be used as the light source for the projector **650**. Controller **642** may drive the DMD **632** (and each of the DMD mirrors). As illustrated in figure 6, the controller **642** may also interface with update ports logic **640**, a user interface **644**, and a projector interface **646**. The user interface **644** may allow a user of the system to select operational options such as which disruptive effects to perform. Conversely the disruptive effects may be controlled based on information received from the projector interface **646**, or from the external port interface 640. A projector interface **646** allows information to pass between the disrupter **620** and the projector **650**. The information may include frame synchronizing information, content location information, or control and disruption information encoded on the content media. The port interface **640** may update operational tables and logic in the controller.

[0082] Figure 7 is a block diagram showing possible locations for a disrupter in a projection system. As illustrated, any number of disrupters may be utilized in a system, either independently or collectively to cause disruptions to the optical beam.

A typical projection system includes a lamp power supply **710**, a lamp **720**, a projector **730**, a projection lens **740**, and a screen **750**. Modulation may include any method that results in the varying of the intensity of an optical source or signal with time. The modulation may further include any method that results in the switching on or off an optical source or signal with time. The only requirement to successfully practice the present invention is that at least one disrupter be utilized somewhere in a system to disrupt the final output.

[0083] Disrupter 1 **701** may be integrally located in the lamp power supply **710** and generate disruptive effects by modulating the lamp source through the output of the lamp power supply **710**. Disrupter 2 **702** may modulate the light power between the lamp power source **702** and the lamp **720**. This location preferably may have the same effect as modulating the lamp power in the lamp power supply **710**. The lamp **720** may also contain a disrupter 3 **703**. This disrupter may use various means to control the output of the lamp **720**, including modulating the supply or producing an optical interference with the lamps output. Means for generating optical interference may include any number of optical shutters known in the art. Disrupter 4 **704** may be located between the lamp **720** and the projector **730**. This disrupter 4 **704** may further disrupt the projected image by modifying the lamps light beam into a disrupted light beam before it reaches the projector **730**. Disrupter 5 **705** may be located internal to the projector to disrupt the optical beam either before or after the content is introduced into the optical beam. Disrupter 6 **706** may be positioned between the projector **730** and the projection lens **740** to disrupt the optical beam after content is

introduced into the optical beam but before the optical beam is focused for the screen **750**. The projection lens **740** may be any suitable lens for facilitating the projection of the optical beam coming from the projector **730** for display on the screen **750**. This lens assembly may include disrupter 7 **707** to disrupt the optical beam. A disrupter 8 **708** may be placed external to the projection lens to generate a disruption of the projection optical beam. This location may be extremely convenient when it is difficult to install a disrupter in any of the previously discussed locations.

[0084] One skilled in the art will recognize that optical signals may be disrupted at any point in an optical system, including locations not shown in this diagram. The point being that there are numerous places from the initial generation of a light source until a final light beam reaches a recording sensor that a disruption effect may be inserted. Using a disrupter in secondary image sources that simultaneously display images upon the screen **750** may even create disruption effects.

[0085] To maximize disruption effects, it may be advantageous to preprocess the content. Figure 8 is a flow diagram showing possible content processing steps. The flow starts at step **S810** with some original content. Step **S812** processes the original content. The processing at this step may include analyzing the original content to determine optimal locations and disruption techniques to use throughout the content. The disruption techniques and data may be generated for a variety of independent disruption mechanisms. These independent disruption mechanisms may include protections for a variety of IRD's. Next at step **S814**, the content may undergo specific modifications based on the analysis made during the processing step **S812**.

The content may also undergo generic modifications to whole frames at this step. For example, the content may be "overexposed" for the whole or part a frame. The content maybe separated and modified based on color. These modifications may assist in the presentation of effects at display time. At step **S816**, the process may add effects and security information to the content media. The disrupter may interpret and act upon the effects and security information. This information may further include security measures to assure that content is only displayed where and when it was intended for display or to synchronize effects to the presentation of the content. The processed content may be stored and distributed on multiple independent media. An example includes encrypting effect data so that only specific projectors may properly show the content. On a film based system, the audio may be independently encrypted and delivered on an independent media, thus enhancing security. The final step **S818** illustrated in figure 8 is to generate copies of the content for distribution.

[0086] In some embodiments of the present invention, it may be helpful to modify only part of the optical beam. For example, one may wish to minimize the attenuation of the final projection. The block diagram in figure 9 shows how it may be possible to split, disrupt, and then recombine an optical beam. Optical splitter **914** may split optical beam **932** into two different beams with similar or dissimilar (i.e. blue and red split) content. A first optical beam **950** may travel to an optical combiner **916** undisrupted. The path followed by optical beam **950** may include reflection by at least one mirror **918** or modification by optics (not shown). The path followed by

optical beam **940** may include being disrupted by at least one disrupter **920** or modified by optics (not shown). It may be important that the optical delay is relatively equal for both the disrupted beam **940** and the undisrupted beam **950**. Optical combiner **916** combines the separate optical beams **950** and **940** into a combined optical beam **960**. This combined optical beam may now include some disrupted content. For example, optical splitter **914** may split content by color, using a device such as a prism, such that only blue content is sent to disruptor **920** and all other content is not modified. Further splitter **914** could also split all wavelengths equivalently (either temporally or continuosly, such that each split beam is a percentage of the total beam. In another example, the splitter **914** could split the content spatially such that disruptor **920** modifies only the selected area before the content is recombined.

[0087] It is possible to add a disruptor as per the present invention to a conventional film projector as shown in figure 10. A disrupter lamp source **1000** may replace the lamp source of the conventional projector. The disrupted light beam emanating from the disrupter lamp source **1000** is preferably focused by optics **1010** onto the back of the film in conventional projector **1020**. The projector may operate in a usual mode to project an image beam **1030** which contains a disrupted copy of the film content onto a screen **1040**.

[0088] Figure 11 illustrates a disruptive projector system using a disruptive projector in combination with a conventional projector. In this embodiment, the disruptive projector **1100** generates a disruptive light source for a conventional projector **1130**.

A lamp **1110** generates a light source which may be focused on the DMD **1114** by optics 1 **1112** through an optional color wheel **1116**. The color wheel **1116** may be any type of light filtering device. A DMD controller **1126** may control the DMD **1114** using control signals **1120** and data signals **1122**. A power source **1102** may provide power for the disruptive projector **1100**. Each of the DMD mirrors on the DMD chip **1114** preferably reflects light from the lamp **1110** to either the optics 2 **1118** or back into the lamp **1110**. The data signals **1122** may include mirror position data for the mirrors on the DMD chip **1114**. The control signals enable the DMD chip to accept the position data and to position the mirrors.

[0089] The light beam **1129** which is reflected from the DMD chip **1114** intended for the conventional projector **1130** may be focused by optics 2 **1118** onto the plane of the film **1132** in the projector **1130**. In some embodiments,it may be desireable to soft focus light beam **1129** (focus the beam near the plane) to minimize visibility of the effects, in the displayed image, to the human visual system. It may be advantageous to automate the optics focusing. The light beam **1129** then travels through film **1132** and is preferably focused on a screen **1140** by optics 3 **1134**. The image projected on the screen may now contain a composite of the disrupted light source and the image on the film.

[0090] When a color wheel **1116** is used, the DMD controller **1126** may produce disruptive effects that are color specific by synchronizing the disruptive effects with the wheel. The DMD controller **1126** may control the color wheel **1116** and obtain position information about the color wheel **1116** through wheel control lines **1124**. By

generating the disruption effects at varying levels during the times when the light source is projecting through specific sections of the color wheel **1116**, the output effects may become color specific. In some disruptive projectors as per the present invention, the DMD **1114** may include multiple light arrays. Color effects may then be generated simply by segregating the effects to the discrete DMD's.

[0091] The disruption effect generated by the disruptive projector **1100** may either work in synch with the shutter in the conventional projector **1100** or simulate the shutter itself. Typically, a shutter on a conventional projector **1130** has a defined blackout period during which there is film advancement by a film advance mechanism **1138** and also a matching blackout period evenly spaced with the advancement blackout period to minimize flicker. The DMD controller may then introduce disruptive effects during the remainder of the cycle. The projection control **1136** may communicate the shutter closing times to the DMD controller **1126** over an inter projector communications line **1128**. Data coming over the projector data communication line **1128** may include other data, for example, audio data, lamp control data, film tracking, film identification, focus, and power.

[0092] External interface **1127** may provide disruption instructions for use in the presentation of content. This interface **1127** may be unidirectional to input the instructions or bi-directional to allow interactive instructions.

[0093] This novel configuration of utilizing a disruption/digital projector with a conventional (i.e. film) projector illustrated in figure 11 may operate in a multitude of configurations. When no film is present in the conventional projector **1130**, it may be

used as a digital projector with or without disruption. When there is film present in the conventional projector **1130**, it may be used as a combination or film projector with or without disruption. In this configuration, data from the interface **1127** may provide operational information. This information may include instructions, data, images, and disruption data.

[0094] Figure 12 shows light array **1200**. The light array **1200** illustrates a two-dimensional array consisting of a multitude of elements. The elements are located at the intersections of two axis's creating rows and columns. The identity of each element may be the intersection of the row and column that it intersects. For example, element 1,1 is located at the intersection of row 1, column 1. Element (1,n) is located at the intersection of column 1 and row n. Element (m,n) is located at the intersection of column m and row n. One skilled in the art will recognize that other combinations of array elements may be possible including the use of more than two dimensions.

[0095] The present invention may be practiced using a DMD MEMs light array device manufactured by Texas Instruments of Dallas, Texas and found in the Kodak DP800 projector marketed by the Eastman Kodak Corporation in Rochester, New York. Each element of this device is a discrete mirror that may be independently steered creating (m x n) possible discrete disruption zones. Figure 13 illustrates a DMD device. To control the discrete mirrors, this device requires loading column and row position data for the mirrors. Data may be loaded into the device as sequential 16 pixel wide column data. The sequential column data for column 1 **1310** through

column n **1312** is loaded independently for column 1 **1320** through column c **1322**.

[0096] Figure 14 is a block diagram showing more details of the DMD device. Figure 15 is a timing diagram showing a possible operational sequence to operate the DMD device. The DMD may have DMD mirror cells **1400** that include a DMD mirror array **1404** and a DMD mirror memory array **1402**. Preferably, there is a one-to-one relationship between the DMD mirror array **1404** and the DMD mirror memory array **1402.** Serialized Column data **1450** is clocked into a row latch **1430** through a multitude of shift registers **1420**, one shift register for each column by clock **1451**. The shift registers convert the serialized column data to parallel form for loading into a DMD mirror memory array **1402**. Asserting row latch signal **1452** preferably causes the data in the shift register **1420** to be stored in row latch **1430**. Asserting row write **1455** may cause the data in row latch **1430** to be stored in a row of DMD mirror memory cells determined by row selector **1440**. Asserting subframe strobe **1454** may reset row selector **1440** to zero. Likewise the row selector **1440** may be incremented by a row incrementer **1453** signal. Finally, the data in the DMD mirror memory array **1402** may be used to position the mirrors in the DMD mirror array **1404** by assertation of a DMD refresh signal **1456**.

[0097] As illustrated in figure 16, DMD controller logic **1600** may drive the DMD chip (not shown). The DMD controller **1600** may include a user interface **1610**, an image generator **1612**, a programmable logic device (PLD) **1622**, a clock circuit **1624**, and a DMD refresh signal generator **1626**. The output of the DMD controller logic **1600** may include control signals **1630**, and column data **1640**. The PLD may implement

logic to generate signals such as those signals disclosed in figures 14 and 15 for output to a DMD chip. This embodiment may require DMD refresh logic **1626** to produce a tri-level DMD refresh signal. The clock logic **1624** generates a master clock for the DMD controller **1600**. The rate of this clock may vary depending upon the disruption effect required. Image generator **1612** may provide image data or image effect data for the system. In some embodiments, the output of the image generator **1612** may include the final content. In other embodiments, the output of the image generator **1612** may only include disruption data. In yet further embodiments, the data may include disrupted output content. Data for the image generator **1612** may be provided from external sources over interface **1613**.

[0098] Figure 17 is a block diagram of an aspect of the present invention showing an image generator **1700**. The image generator **1700** starts with image data **1702** and/or pattern data **1703** which that may be internally generated, externally generated, preproduced, or dynamically produced. The image data **1702** may be encoded or unencoded display data with varying frame rates. The pattern data **1703** may likewise be encoded or unencoded disruption data with varying frame rates. The image data **1702** and/or the pattern data **1703** may further be pixel specific data or block specific data. The display rate may be varied independently for any pixel or block.

[0099] Examples of pattern data **1703** may include sprites or fonts. Image data **1702** and pattern data **1703** may be input into effects logic **1712**. The effects logic **1712** preferably converts the display data to a time specific effect pattern (hereinafter

referred to as 'pattern') determined by a pattern selection **1714**. Preferably, the effects logic **1712** may be a simple lookup table or a more complex logic subsystem. The pattern outputted includes data to specify the DMD mirror positions over a multitude of subframes. A subframe may be a single frame in a multitude of frames that are intended to be displayed as a sequential group. One skilled in the art will recognize that the use of subframes is not the only way to output pattern data but merely a discrete example of a means for generating such a pattern. Further, there may be no requirement to use conventional frames. In this case each pixel or group of pixels may be changed at any time independent of the rest of the image. This may allow for localized effect areas in the image able to produce independent effects. In some embodiments, either the image data **1702** or the pattern data **1703** may be null.

[00100] The pattern is loaded into image transpose logic **1720** along a first logical axis **1722** sequentially. The subframes may then be extracted along a second logical axis **1726**. This procedure of writing patterns and extracting subframes transposes the patterns into subframes in a form that is usable by the DMD driver **1740**. It may often be convenient to store the subframe output in an image transpose buffer **1730** before feeding the subframes into the DMD driver **1740** which will drive the DMD **1750**. The transpose buffer **1730** may provide timing relief between the DMD driver **1740** and the transpose logic **1710**.

[00101] Because loading a DMD image may take a considerable amount of frame time, embodiments may use dual sub-frame display data to DMD pattern data

converters. As illustrated in figure 18, the image data **1810** may be fed into either image transpose logic A **1820** and/or image transpose logic B **1822.** One of the transpose logics may be a master and the other a slave. The master may decide which logic block will process each subsequent influx of image data **1810** and pattern data **1811**. The output of image transpose logic A **1820** may be buffered by image transpose buffer A **1830** and like wise the output of image transpose logic B **1822** may be buffered by image transpose buffer B **1832**. Under control of the master, one of the image transpose logics may present output subframes to the DMD driver **1840**. The DMD driver **1840** may then drive the DMD **1850**.

[00102] Figure 19 shows a pattern based disruption generator. In this embodiment, the input light beam to the DMD **1930** is modulated by the disruption pattern. For example, text or characters may be used to drive the DMD. Pattern data **1910** may specify to the pattern memory **1912**, what characters to generate. A pattern selector **1914** may determine what pattern type will be used. The different types of patterns may produce different disruption effects. The output of the pattern generator **1912** may be output to a DMD driver **1920**. The DMD driver **1920** may load the data into the DMD **1930** as a series of columized data **1922** where the DMD accepts data for colums 1 **1932** through column n **1934**. The data may load each column row by row as illustrated in column n **1934**.

[00103] Figure 20 is a diagram of an aspect of the present invention showing insertion of disruption text on an image. A sequence of disruption frames **2000** may have character disruption text inserted in the frames per a pattern designed to cause

disruptive effects. The frames may be projected through film **2020** containing content. A first resultant image **2030** is what an IRD might detect while a second resultant image **2040** is what a person might perceive.

[00104] Figure 21 is a diagram of an aspect of the present invention showing a multitude of font projection sequences. Also illustrated in figure 21 are how an electronic device such as an IRD or digital camera and a human might detect or perceive different images. Sequences **2110**, through **2124** show black and white block sequences. Sequence ~~**2210**~~ 2110 projects all white blocks. Both electronic detection and humans may perceive white. Sequence ~~**2212**~~ 2112 projects all black blocks. Both electronic detection and humans may perceive black. Sequences **2120**, **2122**, and **2124** show various 50 percent duty cycles of black and white blocks. In all of these cases, the human may perceive gray whereas the electronic devices may see either black or white as shown.

AW 6/24/04

AW 6/24/04

[00105] Sequences **2130** through **2152** show variations of 'C' and inverted 'C' characters. Again, in each case, the electronics will detect discrete characters, including sequences of characters such as seen in sequence **2150** and **2152**. Where there are equal numbers of "C" and inverted "C" characters displayed at a rate faster than the human eye can perceive, the intensity of the foreground and background appear to be equal levels of gray and may not be distinguishable. Sequence **2130** projects all 'C' blocks and both electronic detection and humans may perceive 'C'. Sequence **2112** projects inverted 'C's. Both electronic detection and humans may see the inverted 'C'.

[00106] Figure 22 illustrates a disruptive technique where a majority of a screen **2200** (shown in hatch) displays content at a different frame rate. A separate disruptive effect may be generated over a smaller zone of the screen **2210**. This technique may take advantage of synchronization circuitry that some IRDs have. The synchronization circuitry allows IRDs to synchronize their shutters to external light sources such as artificial lighting or display screens. However, the synchronization circuitry may only synchronize to a single frequency. The IRD will preferably synchronize on the majority frame rate, thus enhancing targeted disruption in the smaller zone **2210**.

[00107] Figure 23 illustrates a light switch array **2310** and a mirror **2300** combination wherein the light switch array **2310** occupies an area of the mirror **2300**. This effect allows disruption effects to target a particular area of an image. An advantage of this configuration is that it allows an effectively higher resolution attack over a smaller area using a light switch array **2310** than if the same light switch array **2310** were used to attack to whole image. Another advantage of this configuration, is that it may minimize the heat that a light switch array is likely to be subjected to. This configuration may be generated either by combining the mirror **2300** and the light switch array **2310** physically, or virtually by only steering array mirrors in an attack zone while leaving the other array mirrors idle.

[00108] It is possible to practice the present invention to provide varying degrees of disruption resolution. For example, one may create disruptive flashing effects by disrupting the image in whole. One may also create localized disruption effects by

focusing the disruption effects on smaller areas or zones of the final image. The disruption zones may eventually become so small that the disruption zones reach or exceed the resolution of the original content. Using light arrays may create higher resolution disruptions. Light array technologies include LCD display devices, optical shutter devices, artificial eyelid devices and MEM's devices.

[00109] Figure 24 shows an attack based upon the interlace processing on some IRDs. Some video standards such as NTSC and PAL display images as two interlaced frames. A typical 1/30 second interlaced frame may comprise two 1/60 second fields. A first event **2400** may be captured once in a 1/30 second period but laid down in the recorded copy as a second event **2410** in a first 1/60 second field **2430** and a third event **2420** in a second 1/60 second field **2440**. The result is that each single invisible short attack image generated may be displayed twice in a temporally stretched form preferably making that attack image visible when viewed through an IRD.

[00110] Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. For example, image generation has been multiply illustrated as being produced by projector systems. One skilled in the art will recognize that any image generation device with the proper timing may be used to create images as per the disclosed invention. Therefore, unless such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.